So You Want to Be a Chemist?

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SO YOU WANT TO BE A CHEMIST?

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PREFACE

Interviews with young people preparing themselves for careers in industrial chemical work have led the author to the belief that these students might find something of interest in a discussion of the various kinds of work which chemists and chemical engineers actually do when they get out on the job.

Similarly other conversations with men in business, men who have heard of chemists, but who really have not much of an idea as to how they work or what they can accomplish, have made it seem that some of this group too might be interested in learning something about the kind of help they could expect to get from chemically trained people.

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With the thought that a brief discussion of the activities of the chemist and chemical engineer in industry might be of help by giving to those

unfamiliar with that work a quick look at the subject, the following pages have been prepared. If to some readers the presentation seems at times to be a rather flippant handling of material usually treated seriously, it should be said that there is a defense to be offered. Laymen are apt to regard us as an uncompromisingly serious-minded lot and unfortunately when they have decided that about us, it is sometimes hard to get them to accept us as members-in-good-standing of a business organization. There seemed to be some point in reminding ourselves, and perhaps others as well, that after all, chemists are people too.

HERBERT COITH.

WYOMING, OHIO,
May, 1943.

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FOREWORD

Dr. Coith is a shy author. I had worked with him through a hot Washington summer in an improvised office which reverberated with perpetual conferences and shouted telephone conversations, but he had given no inkling of an instinct for authorship, save for that afternoon when he worked three hours trying to redraft a WPB legal order so that it could be understood.

It took Mrs. Coith's initiative to produce "the manuscript" one evening—the manuscript which Herb had labored on spasmodically over many years. And as I became absorbed in chapter after chapter, each with its introductory ballad, its direct approach and its apt examples, embarrassment flushed his face with my every comment.

This book is intensely practical. It is written by a man who glories in being a chemist, and who has a broad concept of the chemist's responsi-

bilities to his fellow men and to society. Its values may be greatest to the young chemist and chemical engineer in his twenties—in the years of graduation from school and introduction to industry. It is definitely not a sales appeal for the youngster to pick a chemist's career. Rather, it is an honest and perspicuous analysis of the varied professional functions and responsibilities of the chemist, of the importance of his jobs, and of the characteristics which are required to perform them.

Older men will relish the mature philosophy of the author, and will conjure illustrations from their own experiences to parallel those which Dr. Coith presents. The young college student may sometimes be bewildered because his practical world is not what he had imagined. But all can profit from the lucid exposition of the chemist's professional life and of his opportunities for service.

WALTER G. WHITMAN.

WASHINGTON, D.C.,
May, 1943.

SO YOU WANT TO BE A CHEMIST?

Chapter I

WHAT IS A CHEMIST?

We're a wondrous big division of a prosperous company.
We're the chemists.
Bum! Bum!*
We're the chemists.
We consist of a director and a young washboy and me
And other chemists.
Bum! Bum!
And other chemists.
Some cynical folks around the place just wonder what we do,
And frankly, there are days, b'gosh, when some of us wonder, too,
But we'll show the dirty doubters something new before we're through.
We're the chemists.
Bum! Bum!
We're the chemists.

But what is a chemist? Yes, what?

And immediately someone raises a counter-question, perhaps after the manner once made widely famous by a couple of well-known gentlemen of color:

* Words inserted to round out the rhythm, not adjectives referring to chemists.

"What's yo'h idea in bringin' that up?"

Well, there are several ideas. In the first place, and purely from a selfish angle, it would be nice if it were possible to give the layman a notion of what chemists do, so that when we admit that we are chemists, they would not reply with that inspired question, "Oh, so you work in a drug-store, do you?"

Something also would be gained if people in general got enough of an idea of the difference between a chemist and a soothsayer so that Cousin Elmer or Old Man Dowie or someone else would not continually be bringing us a little bottle of this or a can of that or a hunk of the other to examine, open the conversation with that flattering challenge, "Say, you're a chemist. What's this made of?" and then stand by expectantly, waiting for us to take a look or a sniff or a taste and give a formula for reproducing the stuff.

In the next place, maybe it would be interesting to the thousands of students in schools scattered about the country who are preparing themselves for chemical careers to know something about whither they are bound and what sort of work

awaits them when they face the world. Do the pretty pictures in the magazine advertisements—those showing learned-looking sages with pointed beards and nice white jackets like the ones dentists and soda-fountain clerks slip on when they go to work—really represent a chemist or not? Will they, the aspiring students, some day be peering into a beaker or a test tube just as those boys in the pictures do, with a microscope at one elbow, a Bunsen burner at the other, and an artistic, if not realistic, blown-glass thingumajig in the offing ready for the next experiment?

Or those other pictures which occasionally appear in the magazines, showing just the kind, honest face of the "chemist" who thinks so-and-so about some tooth paste or cosmetic, in much the same way as a movie queen hails a certain lipstick or cigarette or as the Duchess of Bilgewater eulogizes something dainty in brass beds—do they show the chemist in his ultimate transcendent development?

If pictures of the first sort, the chemist practicing his trade, do not truly reflect how chemists work, and if pictures of the second sort, just the

calm face of the scientist in repose, do not show what the chemist may hope some day to become, then what sort of future does await these students when they finally turn their backs on campus life and start out to demonstrate that the money father spent on their higher education was not entirely wasted?

In the last place (and pay very close attention now, you brothers in chemistry), if we could only get across to more of the country's business leaders a little better idea as to just what chemists *can* do, so that they would realize how much more service they could get from chemically trained men than they are getting, they would be putting us in places of greater responsibility, the demands for our services would increase, and, b'gracious, by and by we would all be getting higher salaries. Verily, a consummation devoutly to be wished, if ever there was one.

With these assorted noble aims we move on to the attack. What is a chemist?

But hold a moment! As a humble scientist turned even more humble by trying to be an author, the writer realizes that anyone attempting

to answer the question under discussion is on his way to controversy because there are so many points of view from which to approach the subject.

No one will expect the typical, deep-dyed researcher who puffs his pipe and ponders over the possible action of nitrosodimethyl-so-and-so on apiole to look at the matter in quite the same way as does the young college graduate-assistant, much of whose energy is sapped in worrying over whether the blasted freshmen will ever learn the gas laws. And neither of them will have quite the same slant as that of the vice-president in charge of production who has agreed to a half-million-dollar chemical-division budget for the fiscal year and who thereafter keeps a slightly flinty weather eye out to see what his company is going to get for the money.

Under the circumstances how easy it would be to fool someone into reading the pages which are to come, without his fully realizing where he was being led, and then have him find out in the end that he had been tricked into investing his time in reading rubbish. Such a thing would never do, and it shall not be!

In order that it may be clear to all you readers, before you wade through many more pages, just what you are in for, we shall set down in the next few paragraphs a brief résumé of what is coming. Take heed! The remainder of this chapter is here for your protection and if, after you have completed it, you *will* read on, don't say you were not warned. You will have gone into it deliberately.

To begin with, let it be known that we propose to discuss the work of the chemist in industry. Because such work is so varied and leads into so many unexpected directions, the field becomes an extremely broad one. Therefore our first task is one of dividing that broad field into a few simpler subdivisions which we can consider individually and which we can then put together and study as a whole.

There are various ways in which the subdividing might be done, and we make no claim that the way we are going to adopt is better than any one of a number of others. But for our present purposes let us consider the work of the industrial chemist as it relates to:

Raw materials
Processes
Finished products

Then, having established the foregoing fields, let us introduce a second set of divisions as follows:

Standards
Laboratory investigation
Plant investigation

And now, having made two simple divisions, let us combine them in a sort of a table, this way:

	Standards	Laboratory investigation	Plant investigation
Raw materials	X	X	X
Processes	X	X	X
Finished products	X	O	O

You will note that under the column headed Standards we have put three X's. These are intended to signify that the chemist in industry is going to concern himself, among other things, with standards for raw materials, standards for processes, and standards for finished products.

Again, there are X's in our chart intended to convey the idea that both laboratory and plant investigations are to be carried out on raw materials and on processes.

When we come to products, however, both under Laboratory investigation and under Plant investigation, we find not X's, but O's. These are not intended to indicate that laboratory and plant studies are not to be carried out on finished products, but to focus our attention for a moment on the fact that much of the investigational work carried out on products is done from a point of view quite different from that done in connection with raw materials and processes. Specifically, the difference referred to is this:

We investigate our raw materials and our processes from our own standpoint or, rather, our company's standpoint. We want to find substitute raw materials, develop improved processes in order to increase our yields or simplify our operations—to lower our costs, to save money. But we investigate our finished products not only from our own point of view, but from the point of view of our customers as well. We want to

develop new products that will be more serviceable to the people who buy our goods, or we want to find better ways for customers to use our present products. To be sure, in the last analysis, these objectives too take account of our point of view because we hope, by making such a study, to lead our customers to feel that they want to buy our products instead of those of some competitor. Nevertheless, there is a distinction that we believe justifies giving separate consideration to certain kinds of investigational work on products. In order to have a convenient name for work in which the customer's point of view is given particular attention, we are going to call it "products service."

Now there are, as we have shown in our tabulation, two types of investigational work: that carried on in the laboratory, and that done in the plant. In order that we may have convenient names for these we are going to designate laboratory investigational work as "research" and plant investigational work as "plant development."

Summing up our discussion to this point, we find we have divided the work of the chemist in

industry into four fields, and the worker in each of these fields concerns himself, though from different points of view, with raw materials, processes, and finished products. We therefore revise our previous chart and construct the following one, which designates the field of work in which the industrial chemist occupies himself.

	Standards	Research	Plant development	Products service
Raw materials.....	X	X	X	X
Processes..........	X	X	X	X
Finished products...	X	X	X	X

In large organizations a whole group of workers may be engaged in each field. In a small company a single chemist may be undertaking to cover all four. But in any case the chart shows the range of activity that has to be considered. Our next step will be to discuss the divisions individually.

Chapter II

STANDARDS

Some analyze the samples that are brought in by the bunch.
Weary chemists.
Bum! Bum!
Weary chemists.
And others grade the garbage grease, then sit
near us at lunch.
Smeary chemists.
Bum! Bum!
Smeary chemists.
And some set specifications telling our buyers what to buy,
While others write "Factory Standards" telling what to do and why.
They help the superintendents out, or anyhow they try.
We're the chemists.
Bum! Bum!
We're the chemists.

We start by taking up the work of the standards department because this work is probably the most obvious and most commonly practiced work of the chemist in industry, and, as such, it will be somewhat more familiar to a greater number of readers than would any of the other

divisions with which we might begin. Again, an understanding of standards work will give us the best possible foundation for discussing the subjects that we want to develop later. It will help us get our feet on the ground because it deals, for the most part, with things as they are. When we come to research, plant development, and products service, we are going to be considering mainly changes—substitute raw materials, alternate processes, or improved finished products. But standards are set to guide and control operations as they are currently being carried out.

For that reason, incidentally, a man starting his first job with a concern can look to the standards department to obtain information necessary for orientation in his new work.

There is not much mystery in the work of a standards department. Its primary function is to ensure uniformity of finished products, and, because uniformity in these cannot be controlled efficiently without uniformity of processes and uniformity of raw materials, standards and specifications are established and maintained for all these.

But it is not enough simply to set standards. Instructions for meeting and maintaining these standards have to be given to the persons or departments concerned, and, since such instructions are usually quite involved and include many important details, it becomes necessary to set them down in writing. Thus the standards department becomes a compiler of specifications for purchasing agents, an author of instruction books for plant operators, and a recorder of necessary qualities in finished products.

Setting the standards and writing and distributing the information concerning them, however, does not represent the whole extent of the standards department's job. In fact, it is scarcely the beginning. The real job comes in exercising a constant vigilance over materials, processes, and products to see that the proper quality is maintained. Call it checking, auditing, policing, anything you like, the job remains the same and its watchword, aimed at products that are in any way substandard is this: They shall not pass!

With such an objective before it, the standards department prescribes tests that shall be made on

materials going into a process, materials at various points during the process, and materials as they emerge from the process, to assure everyone concerned that all is well.

But these tests—where are they made, and how? They are made in the testing laboratory by the application of analytical chemistry.

Here, in a sense, we have come to the real beginning of our story, for analytical chemistry, using the term in its broadest meaning, is the cornerstone of all chemistry. It is the fundamental, the *sine qua non* (which I just looked up in the dictionary and which, according to that comprehensive volume, means "that which is absolutely indispensable"). It is the essential tool without which the handicraft of the chemist cannot proceed. It is chemistry's measuring stick.

At this juncture some of our hairsplitting contemporaries, who insist on words being used in their exact meaning, will point out that we are taking in an unjustifiably large territory for analytical chemistry. They will quote our friend the dictionary to the effect that analysis means "ascertaining or separating the elements of a complex

body," and that there is a lot of measuring done in chemistry that does not fit in with that definition. Of course, strictly speaking, they are right. The analysis of a piece of alloy, in which we determine the percentage of the various metals which it contains, lines up with their definition perfectly, but the "analysis" of an oil in which we determine such things as iodine value, saponification number, refractive index, and perhaps various other characteristics, does not meet the ironclad definition of analysis at all. Yet by custom we have come to regard many measurements of physical and chemical properties as belonging in the same general realm as "ascertaining the elements of a complex body" and we have put the whole lot together into that division of our science which we call "analytical chemistry."

In spite of the fact that analytical chemistry is a vital factor in every chemist's every undertaking, it is regarded by some of our scientific coworkers as a matter of minor importance. Occasionally men are unwilling to admit before a group of their fellow scientists that they are connected with analytical chemistry because that seems, in certain

quarters, to stamp them as low grade. Now why is that?

Well, the reason no doubt is that in numerous industries where chemical control is practiced the routine analytical work is carried on by boys who have no chemical background but who have been taught a certain series of manipulations, just as you or I might be taught to tat, knit, or crochet, provided someone could be found with patience enough to teach us. In their environment these laboratory boys are sometimes alluded to as "chemists" so the impression gets abroad, and takes root in the minds of some people who ought to know better, that that is what they are.

We ought to pause for a moment at this point to cry out against those manufacturers who have hired someone to do routine testing for them and thereafter labor along under the delusion that their concern has a chemist. There are all too many companies like that, and the lamentable fact is that such companies don't even know what a chemist is.

Of course, it is true that in smaller concerns a chemist may have to do his own testing, and we do not for a moment mean to suggest that, when

such a condition exists, the work is unworthy of him. On the contrary, we should like to stress the point that no one engaged in chemical activity can afford to take the attitude that a real chemist is above having to think about analytical work. However, performing routine analyses should not be mistaken by anyone as the objective toward which chemists strive. If an organization has a place worth putting a real chemist in, it will probably be worth while to give him a laboratory helper to relieve him of details that require a willing pair of hands but not a chemically trained head.

The foregoing paragraph brings to mind a piece of work done under the supervision of a man whose well-known name brings thoughts of achievement to the minds of those who hear it, but who has unburdened himself from time to time regarding the status (or rather, lack of status) of analytical chemistry. The piece of work referred to required several months for completion and represented an appreciable outlay in time and money. It had to do with learning what happened to a substance during a certain process. The material going into the process was analyzed, as were

the products and by-products coming out; all this for the purpose of determining how much of the substance went into the product, where it was wanted, and how much into the by-product, where it was not wanted. Further, it would presumably be found how the process might be varied to put more of the substance in its proper place, that is, in the product. But alas! After all the outlay of time and money the results were a meaningless hodgepodge. They didn't fit and the accounts didn't balance, so to speak. Notwithstanding this unfortunate lack of consistency, a voluminous and solemn-looking report, which tried to account for the discrepancies, was submitted to the organization that had paid to have the work done. After the report had been received and wondered about a little, some lowly chemist in the organization, who had an interest in analytical procedure, dug into the analytical methods that had been used. He found that, at one point in the vital analysis on which all the work rested, there was supposed to be added a certain reagent, part of which reagent was supposed to combine with the substance being deter-

mined, and the remainder of which, or excess of which, was to be measured by suitable means. From the data thus obtained it was to have been possible to solve the problem. In the work as actually carried out no excess had been used. In fact, only 10 *to* 40 *per cent* of the amount necessary to combine with the substance in question had been used, to say nothing of an excess. As a result, the analyses were all "off" and the entire job was worthless.

Obviously impossible, you think. No reputable consulting chemist could be caught in such a situation. Well, believe it or not, as the cartoon man would say, this thing actually happened. This great and good man, who holds firm to a lofty belief that analytical chemistry is something to be handled by the less capable, permitted money to be spent and human energy to be squandered on a project just because he didn't make sure the fundamental analytical procedure was what it should be.

Analytical chemistry may become routine, and frequently does, but never can anyone safely take for granted that it is not worth intelligent attention.

It is really shameful the way we have run away from the subject of standards, which is what the present chapter originally set out to be about, but as long as we have gone into this matter of analysis as far as we have, we might go just a little further and consider for a moment the possibilities that analytical chemistry offers to men going into industry. If it is so all-important as we indicated a moment ago, perhaps it offers excellent chances. Perhaps! As a matter of fact, however, it does not.

There are some analytical jobs in the research departments of large companies which are not routine, which afford many interesting analytical problems, and which may lead to a fairly good, though never large, salary. But permanent jobs in analytical control work can never be looked upon as very desirable from the point of view of the trained chemist.

In spite of the rather discouraging outlook that control analysis offers, a certain amount of it is very good experience, and in some organizations the control laboratory is actually used as a training ground for newly employed college graduates. In such organizations the analytical-methods books

are virtually preliminary textbooks of the company's processes, so that from them an excellent general picture can be obtained of what goes on in the factory. In addition to this, such a training course gives an intimate knowledge of the raw materials and their properties, what characteristics make them acceptable and what ones make them impossible. An opportunity is afforded for becoming familiar with the intermediate products at every important step, and a knowledge will be gained as to when they are right and when they are wrong. Similarly a thorough understanding of the finished products will be acquired. Knowledge thus gained, by working with samples day after day—hundreds of them—will be ground in and fixed in a manner that cannot be matched by simply hearing about them or observing them. If a company proposing to hire a young chemist is going to put him into the control laboratory for training purposes for a limited period of time, he may regard it as that much more schooling, with pay. But if the company is going to put him there for keeps, he had better be magnanimous and let someone else have the job.

We cannot leave the subject of control analysis without mentioning one very important post in industry—that of head of the control laboratory. We say "post" because that is a word frequently used in connection with the word "diplomatic," and, if the field of chemistry holds any diplomatic posts whatever, the job of head of a control laboratory is at least two or three of them.

Consider the irate foreman who has just drummed off 200 drums of some product that turns out to be a shade under specification. He will have to rework it all, thereby running his costs up and his standing with the management down, unless the laboratory passes it. Are you sure, Mr. Laboratory Head, that your analyst did the work right? Don't you think the stuff will get by with the customer, and can't you pass it?

Think of the superintendent who is going to have to report a big loss of material if the results of your analyses of his inventory samples are what they seem. Are you certain your workers shook the bottles before taking their samples out?

Regard the sorrow of one of the plant chemists who sat up half the night taking hourly samples,

which he left where you would find them in the morning and on which he would like two days' work done by three o'clock this afternoon. Are you sure you can't let something else go and rush these through? This is mighty important, you know! And if you do rush them through and they don't turn out as they were supposed to, are you sure the results are accurate?

Give thought to these and dozens of similar situations. Remember how many places there are where an analysis may go wrong. Keep in mind that your "analysts" are not chemically trained, that they are just boys who have been taught to carry out certain manipulations. You will appreciate the difficulties met by the head of a control laboratory. If ever a man needed patience, tact, and intestinal fortitude here is the place. In case you are looking for a character-building job, this one unquestionably is a "wow," but unless you have a fund of patience greater than has been given to most of us, don't take it on for your life's work if you can help it.

What a confusion of ideas we have set forth about analytical chemistry. First we say it's im-

portant; then we say it offers no future. Next we say it is good training, and finally we close on a note of pity for the man responsible for control work. How about it all?

Well, what we have tried to say may be summed up in something like this: Analytical chemistry is tremendously important. It should be thoroughly understood and its possibilities and limitations appreciated by anyone essaying chemical work, but it must be regarded primarily as a tool to aid in other lines. As a field with a future for the chemically trained, it is usually not a promising job.

In discussing analytical chemistry so fully we have got considerably off the track, so let us return to our standards and mention again what was implied a while ago, that teaching analysts how to make tests calls for another set of instruction books as complete and detailed as those previously mentioned as being necessary for the guidance of plant operators.

When we consider how important it is that all these books, both those for the analysts and those for the plant operators, be not only accurate, but easily understood, we realize that one of the most

important attributes of a standards department man is the ability to organize his information logically and to write it clearly. And lest someone get the idea that it is necessary to write these books only once, let us hasten to point out that in modern industry, with changes taking place as rapidly as they do, such books are in a constant state of revision. Clear writing not only is necessary when the books are first prepared; it is needed daily.

Finally, another phase of the work of a chemist in standards has to do with his relationships with other people. So much of his time is spent in bringing instructions to the attention of factory operators and so much in checking up on the actual work of these operators that, unless he is able to gain their confidence and win their co-operation, they are apt to think of him as an enemy spy rather than a fellow member of their organization. Consequently the standards man must have not only a chemical training, the ability to write, an aptitude for teaching, and a sense for finding where conditions are not just as they should be, but also the knack of making himself welcome among the factory men with whom he has to work.

Chapter III

RESEARCH AND PLANT DEVELOPMENT

There are some who do research* work; into the deep,
deep stuff they grope.
Learned chemists.
Bum! Bum!
High-brow chemists.
And others may nurse a process which some day will work,
they hope.
Earnest chemists.
Bum! Bum!
Patient chemists.
Some work with hydrogenation machines, learning all
their wondrous ways,
And soon they'll give us castor oil we'll think is mayon-
naise,
Then we won't be quite ourselves again for days 'n'
days 'n' days.
That's not just chemis-
try! Bum!
That's also physics!

The word "research" is one of those choice ones that the nontechnical person recognizes as one he

* You will not get the beautiful musical flow of the words in this passage if you mispronounce "research." The accent should be on the second syllable, thus, "There are some who do re*search* work."

has seen in some impressive connection, but the exact meaning and implications of which may be somewhat vague, hazy, and indefinable. It is one of those powerful words which, like radium, vitamin, electron, ultraviolet, and so forth, our brothers in the advertising fraternity use on us to stun, but not kill. But what does it mean? Such different things to different people!

In chemistry there are some who act as if they felt that nothing less than a study of the ultimate composition of matter were deserving of the term "research." Those are the chaps who read somewhere that "the permissible orbits" of something or other "are regulated by the quantification of the angular momentum or rate of sweeping areas." Then they run their fingers through their hair, if any, and continue reading, "So far as any are circles, their radii still proceed" from somewhere to somewhere "as the squares of the natural numbers." Well, that's that.

The members of another group, while not insisting that the word be reserved for any particular field, nevertheless hold a conviction that research must not be tainted with commercialism in any

way. It must be "pure" research and, by inference, the purer the better.

In contrast to the foregoing there is that "practical" group which craves greater yields from some perfectly respectable reaction that is already making a living for several thousand people. More completeness to that reaction means more dividends, and, while these "bigger yield" researchers are regarding the high-brow electron chasers and the other pure researchers with some awe and with perhaps just a tinge of pity, they will feel that research has nobly met an urgent need if it can help them to greater production.

The dictionary, however, tersely informs us that research is "studious inquiry" and if we accept such a definition, even qualifying it as "chemical research," the word becomes so all-embracing that it covers too big a field.

Probably no two large industrial organizations include in their chemical research departments exactly the same types of work, and, since industry itself is not consistent in what the field embraces, it is not to be wondered that the matter is hazy to those outside of industry.

We can, however, get our bearings somewhat by arbitrarily defining research as that phase of "studious inquiry" into the chemical problems of industry which deals with more or less fundamental problems and which is carried out, for the most part, on a laboratory scale. Frequently its objective is the acquiring of basic scientific information, the solution of problems that have no immediate practical importance. Anyone can, without a great deal of difficulty, pick plenty of flaws in this definition. For instance, all research departments spend an appreciable amount of time on problems that seem piddlin' and certainly are far from fundamental. Again, all of them frequently have occasion to work on other than a laboratory scale. But as a means of giving a fairly accurate rough idea the definition still stands. We shall have more to say about research in a moment, but before we do we should say a word about another type of investigational work, namely, plant development.

Plant development is a coined expression used to designate a particular kind of technical work in industry. It is, in general, applied to investiga-

tional work that deals with problems of more or less immediate practical value and it undertakes the study of these problems, for the most part, in equipment of larger than ordinary laboratory scale. It may be thought of as research in tubs and tanks rather than in beakers and flasks. As with our definition of research, plenty of objections can be raised against this definition. Frequently plant development work deals with fundamental problems of no immediate practical value and often it involves a great deal of laboratory work. In spite of the inadequacy of the definition, however, it will serve to outline the general field that we consider as belonging to plant development.

One can readily see that there will be a good deal of overlapping between the fields that we have just defined. Because of this we are going to discuss the two together and we are not going to try to draw a distinction between that which we consider as belonging to one and that belonging to the other. In industry the actual division between the two is dependent on many local factors that need not be considered in the general survey we are about to undertake.

Research and plant development concern themselves, of course, with the three major divisions that we have been using throughout our discussion, namely, raw materials, processes, and finished products. To the layman it may appear strange that in a well-established business there should be much occasion for investigational work in these fields, for it would seem that a concern that had been operating a hundred years, or fifty, or even five, would have things pretty well worked out. The trouble with that thought, however, is that it presupposes a fixedness about production that does not actually exist. As a matter of fact, practically nothing in industry remains the same. Changes in markets, in styles, in living habits, in a thousand and one things, necessitate corresponding modifications in manufacture, and as a result the successful industry must keep alive to the possibilities of things being different and must be prepared to meet altered conditions.

Consider the rubber tire for instance. It used to be guaranteed for 3,000 miles and it was so hard that every jolt that the road gave it was promptly passed on to the motorist. Now we have tires (or

at least we did till the Japs got active) which are easily good for 20,000 miles and which are so cushionlike that, instead of passing road shocks on, they absorb a great proportion of them. What is the difference? Recent tires still had a foundation of cotton covered over with rubber that had been compounded with certain additional things. As the study of tires progressed, there were new "additional things" which the old-time tires did not contain and which made the advantages of the newer ones possible. And the hunt for "additional things" goes constantly on! What effect has this ingredient? What that? Why does the product fail, and how can we overcome that failure? As a result of that constant study we find today's latest "rubber" tires made on a foundation of rayon instead of cotton and without rubber at all!

Again, consider the trusty bar of soap. For years it helped the washboard keep us spick-and-span, but then came the washing machine. The bar had to be whittled up so it would dissolve faster. Enter the soap chip. But why stop there? If a chip will dissolve more quickly than a bar why not something even more rapid? The answer was the

granule, which is a soap bubble, literally, in the wall of which the soap is so concentrated that the bubble hardens and retains its form. But in this field, too, the study has gone on until the most recent granulated "soap" products are made without the chemical compound soap at all.

Even without these constant changes there is room for a great deal of study in practically every industry, for in very few, if any, is everything being done so well that improvements cannot be introduced, and further study in almost any line of endeavor will bring beneficial results.

To start a consideration of specific problems let us assume we have chosen some industry to study and let us consider the raw materials that are being used. We can even start our study before the actual processing of the materials begins. Suppose we pick out one item and give some attention to some of the questions we can ask ourselves concerning it.

What are the effects of various storage conditions on this material we are considering? If the effects are adverse, what can be done about it? Does the material deteriorate with age? It may be

something that oxidizes, dries out, decomposes, ferments, or in some other way loses value upon keeping. If so, can some special condition be devised to protect it?

Again, we may ask whether temperature of storage is a factor. If so, is a cooler place (or a warmer one) available? Does humidity affect it? If so, how can we keep it dry (or moist) either through choosing some different place of storage or through installing suitable humidity-control equipment? What action, if any, does light have on it?

If there are difficulties encountered in storage, can they be overcome by conditioning the raw material before storage? For example, cottonseed, brought in wet condition to a mill, deteriorates markedly because the oil held in the seed develops an "off" flavor when moisture is present. Consequently drying the seed before storing is an aid in preserving the quality of the oil held within the seed.

Still another way of conditioning raw materials before storage is to process them partially so as to get them past the stage where deterioration will take place.

Turning now from the storage of raw materials, we may ask how variations in the quality of each raw material affect the yield or quality of the finished product? What happens if the material is not up to its proper strength? Obviously if we accept something that is below strength, diluted, or adulterated, we are paying for something we do not get, but are there serious consequences in addition to that?

What about the effect of impurities? These may reduce the activity of the raw material chemically. For example, nickel catalyst becomes relatively ineffective if it contains any of the well-known catalyst poisons. Impurities may injure the quality of the finished product through some physical effect, as would be the case if a dark rosin were used in place of a lighter one in ester-gum manufacture. Obviously such a substitution would result in a darker colored ester gum.

How about the intentional addition of some substance to our raw material? For example, chlorophyll, a coloring matter sometimes used to make soaps green, has a much higher tinctorial power if a little copper salt is added to it. From

the standpoint of the supplier of chlorophyll, therefore, it would seem like a smart thing to add copper, thereby giving his product a higher tinting power or enabling him to add some inert diluent so he could offer chlorophyll of a definite tinting power at a lower price. But how would this be from the standpoint of the soapmaker? It just happens that certain metallic salts, and those of copper in particular, promote the rancidifying of soaps materially. Obviously, then, the introduction into soap of a copper-containing chlorophyll is actually a very undesirable thing.

We may next turn to a study of whether we can improve the quality of our raw materials by treating them in our plant before use. If impurities are harmful we can investigate whether purification is feasible, and, if it proves to be, we may want to add that as a normal step in our process.

Again, some form of activation of our raw material may prove helpful. This sometimes may be a chemical activation, such as the treatment of a bleaching earth with acid to make the earth absorb colors more readily, or it may be a physical

activation, such as the finer grinding of some pulverized material that is to enter into the reaction.

Turning from the raw material itself now, what about the containers our raw material comes in? Would the substance be kept in best condition if it came in bags, barrels, boxcars, or what? Or would it come in just as good condition, but at a lower price, if we bought it in some other form of container?

Still another point to consider about raw materials is whether we can do more than we are now doing in the matter of recovering and re-using the materials. Of course, most raw materials are used up in the process, but frequently there are some that are not. For example, a decolorizing carbon, after being used, still offers some possibilities, for it may be washed and subsequently treated to reactivate it, thus becoming available for reuse. But does such reactivated material give as good results as does the new, and can it be reconditioned more cheaply than the new can be bought? There is no use bothering to recover it unless some advantage is to be gained therefrom.

So much for existing raw materials. What about substitute raw materials? The immediate reaction to that question probably is that, if the present materials are proving satisfactory, why bother with casting about for substitutes. To that point the answer is simple. There are three reasons for looking for alternate raw materials. One is to enable us to make a better product. The second is to enable us to make the same quality of product at a lower cost or by means of more advantageous processing. The third, and in wartime perhaps the most important of all, is to permit us to continue making a product when the customary raw materials have become unobtainable.

Considering the matter of cost for a moment, we can readily see that it will be to our advantage to have raw materials that are interchangeable so that we can take advantage of fluctuating market conditions. If we have a choice of two or more materials for a single use we can buy the one that is currently the best value. Incidentally, it is a pleasant situation if we can let the man who sells us our raw material know that it is possible for

us to get something elsewhere that will serve our purposes. It keeps him so much more reasonable and attentive.

Right here, incidentally, seems to be an excellent place to make a very important point in connection with our raw materials. When we are buying raw materials we are buying, not goods, but rather what the chemist calls "properties." In other words, we are buying characteristics or attributes. What does that mean? Just this. We are concerned, not with what the materials are, but with what they will do. For example, suppose our factory is a paint factory and that we are buying white lead to make paint. In the last analysis, when we buy white lead the thing we are really after is not white lead at all, but rather that property or attribute which is described as "covering power." What we want is something we can put in our paint which will cause the paint, when spread on a surface, to cover that surface and make it look white. Of course, there are incidental factors such as the effect on the oil in the paint, the effect on the life of the paint film, and so on—but the primary thing we are buying

is white covering power. If we can get the same effect from some zinc compound or some titanium compound or any other kind of a compound, we are interested in it, assuming that its effect on other factors, such as durability of the paint film, and so on, is not objectionable in some way.

If there are two or more raw materials that have the properties needed for a given manufacturing process the next problem becomes one of evaluating them. One may cost twice as much per pound as another, but if its effect is twice as great it may well be worth the difference. In fact, it may permit some operating short cut or convenience which makes it more desirable even though its actual effect is not twice as great. With the foregoing in mind, then, we can see that our study of substitute raw materials may follow along several lines.

Among other things we shall make a comparison of kindred raw materials. If our process, for example, is a textile process in which palm-oil soap is used, how about using tallow soap or olive-oil soap or oleic-acid soap in its stead?

Again, we shall study the effect of blending raw materials or the intentional addition of foreign substances. Perhaps a catalyst that we are using can be made more active by adding to it a small percentage of some other material that by itself is no catalyst at all.

We shall study materials with similar properties. If our problem is one of heating a still, for example, shall our source of heat be a solid—coal or coke—or shall it be liquid—fuel oil—or shall it even be gaseous—natural or artificial gas? Economy may suggest one; simplicity of operation may demand another. We must consider the merits and shortcomings of each for the particular problem at hand.

Perhaps we can improve the quality of our raw material, or get the same quality at a lower price, by choosing a material made by a process other than the one ordinarily used. For example, if we are using aniline in our process, we have a choice between that synthesized from nitrobenzol on the one hand or from chlorobenzol on the other. Is there any preference, under our particular conditions, for one over the other?

Again, if our raw material is a natural one, differences in treatment of it may mean differences to us. Copra (coconut meats), which is used to make coconut oil, is frequently dried where it is grown and shipped to some other point to have the oil pressed out of it. The drying may be sun drying or it may be kiln drying. Does it make any difference in the mill when the oil is pressed out which method of drying has been used?

Or we may choose a synthetic raw material in place of a natural one. If the price of a natural product gets too high, or if its source is no longer available to us for some reason, a material of synthetic origin is frequently substituted for it. The war has brought many instances of this sort of substitution, for example, synthetic rubber. Sometimes we choose a natural product from one geographical location in preference to that from another if quality or cost factors make this desirable.

Still another possibility to be considered in connection with raw materials is making these ourselves instead of buying them. The determining

factor in deciding whether this is wise or not is usually one of cost.

What about the physical form of the materials? This has to be considered not only from the standpoint of cost, but also from that of convenience of handling. Is it to our advantage to receive it as a solid or as a solution? For example, calcium chloride is available in solid form in metal drums, but it is often used as a solution. Hence, to use it from the drums involves splitting open the container, breaking out the chunks of material, dumping them into water, and dissolving, all of which costs money. On the other hand, the material can be bought in solution in tank cars. To use it when purchased in such form involves simply pumping it, or even just allowing it to flow, out of the tank. But when it is bought in solution there is the matter of paying freight on water. Under the conditions of our particular plant, which is the cheaper?

In the case of some solid materials there is a choice between flakes, with their relatively great surface exposure, and cakes, which are compact and hence easily handled. Stearic acid, for ex-

ample, can be had in either form. Is it more advantageous to us to have the one or the other? Price and convenience again have to be considered.

Turning now from raw materials, we take up the work of the technical investigator in connection with processes and equipment. The first thing we shall want to do is to acquire a thorough understanding of each step in the process as it is being carried out and of each piece of equipment that is being used. What are the chemical reactions involved? What physical changes are brought about? Why is the temperature of the reaction what it is? If a vacuum is maintained, how much and why, and what would happen if it were more, or less? As to the equipment, we must know not only just what chemical and physical changes are going on in each unit and why those changes are desirable, but also what conditions of the equipment are favorable to the beneficial changes and what ones promote detrimental changes. To learn the latter we shall have to study systematically such factors as time, temperature, load, and so forth. For example, if the piece of equipment we are studying is a still,

what is the most desirable-sized charge to feed to it at the start of the operation? How rapidly should distillation be carried out? If the still is operated under a vacuum, how much of a vacuum should be carried? Questions supplementary to the foregoing are: What will happen if a larger charge is fed? A smaller one? What if the distillation is carried on more rapidly? More slowly? What is the effect if a higher vacuum is employed? A lower one? If some desirable end cannot be attained without, at the same time, some undesirable condition entering in, then what can be done to obtain the beneficial effects without the detrimental ones?

To help in gaining an understanding of the whys of both the process and the equipment, one of the first and most important tasks which the investigator can set for himself is to make a set of "toy" equipment. On the face of it that may sound a little silly, but one of the fundamental jobs in connection with the studying of a process is to be able to carry it out on a laboratory scale with such exactness that the results obtained in the laboratory can be reproduced in the plant. It is to enable

the investigator to do this that the small-scale equipment is necessary.

To the man who has not tried to duplicate plant performance on a small scale the difficulty of such an undertaking may not be apparent. But when we consider, for example, the difference in the time it takes to cool a beaker of liquid from, say 100°C. to 25°, just by letting it stand at ordinary temperatures, as compared with the time required to cool, say, 5,000 gal. of the same material stored in a tank, over the same range of temperature, we begin to get an insight into some of the difficulties involved. Let us suppose crystals are separating from this solution. Those depositing from the relatively quickly cooling beaker will certainly be far different from those separating from the slowly cooling large mass. Or again, let us suppose the material is liquid at 100°C. but solid at 25°, and let us assume that our problem is one of settling out certain constituents from the liquid. Obviously the slowly cooling large mass will have a much greater opportunity to settle before it solidifies than will the quickly cooling beakerful. We therefore have to devise a

means of cooling the small mass at the same rate as the large. It may be that ordinary laboratory equipment can be used to duplicate the plant conditions we are studying, but the chances are that it cannot. The resourceful investigator not only makes use of the standard equipment available, but also calls on the glass blower, the machine shop, and the carpenter shop to devise small-scale units for reproducing the conditions existing in a factory process.

It hardly seems necessary to discuss it, but someone may raise the point as to why we want to experiment on a small scale. Why not do our experimenting on the regular production units?

Sometimes the large units can be used to excellent advantage and when they can it certainly is preferable to use them. However, there are two very good reasons why that usually is not a feasible plan. In the first place, production units are ordinarily being used by production men to produce, and the experimenter is an intruder, a "clutterer-upper" of normal free-flowing activity who is not going to be warmly welcomed. He cannot carry on his work without being in the

way and consequently he is usually kept out. In the second place, when one is experimenting he is gambling on the outcome. True, he probably plans his experiment to give a favorable result, but things may not happen as he expects, in which case it is ever so much more comfortable to ruin a few hundred grams of material than a few thousand pounds.

If it remains necessary to carry on experimentation on a production scale the two factors we have just mentioned will prevent a lot of experiments ever being tried at all. Every investigator sooner or later gets ideas so crazy he would not feel like risking their trial on a big scale, but in a small unit he is willing to take a chance. And sometimes such crazy ideas work.

The small-scale equipment frequently can do things which large-scale cannot. For example, it is frequently easier to get a high vacuum on a small scale still than on one of a full plant size. Consequently with our small-scale equipment we may be able to go even further than before in a systematic study of the results obtainable by varying the conditions of the process. The factors

of temperature, pressure, time, and so forth, to which we gave attention on our plant-size equipment, can receive a more complete and detailed study when our small-scale equipment is available.

The nature of the process we are studying will, of course, suggest what variables are worth looking into. It is not practicable to try to set down all the types of things that are worth studying. But an active imagination turned loose on any process will think of many things that will bear studious inquiry.

Such a survey of the effects of varying a process as we have just discussed will, in all probability, result in the finding of ways of simplifying the process or of altering it in some beneficial manner.

Again, small-scale equipment and a thorough understanding of the process can sometimes be turned to advantage in locating trouble in large-scale production. True, after we have gained a thorough understanding of the process through our study we shall have less difficulty in our big-scale operation. But let us assume that in a process consisting of several steps some trouble has arisen in

the large-scale operation which we cannot correct. Our miniature equipment proves a valuable tool in determining the source of the difficulty. We take a sample of the product after the first step of the process and finish it in our small-scale setup, where we can control conditions very carefully. The finished product from the sample turns out to be standard. That gives big-scale operation No. 1 a clean bill of health, for if the sample had been off, the damage would have been done to the product that was finished up in the small-scale unit.

Next we take a sample from big-scale operation No. 2 and finish that up on our small equipment. This time perhaps the finished product comes out subnormal; we have therefore convicted operation No. 2 of being at least partially responsible. Similarly we check the other operations in turn and then, having found which one, or ones, are giving the trouble, we concentrate our investigation in the plant on those points which have been shown to be wrong.

Another use made of the small equipment is in the application of a process to other materials.

Suppose we have developed a machine for puffing wheat to make breakfast food. What will we get if we puff other materials with it? For example, can we take some organic waste product and, by puffing it, develop a porous product that is suitable for insulating purposes?

Still another use of the small-scale units is in the production of small batches of either regular or special materials for submitting to prospective customers. Suppose our plant units cannot operate on a quantity less than 30,000 lb. and that one of our most important customers has asked for a 10-lb. sample of a particular product which we haven't in stock. It is a real help to have a small-scale unit, which will enable us to make the proper-sized batch and at the same time to duplicate plant production.

So far we have kept our investigator on existing processes and equipment. What about new procedures and new machines for making the same products?

There are two reasons for considering a change—to produce a better product and to produce a product of the same quality at a better price. But

with these two objectives before him every alert manufacturer is constantly on the lookout for a better way of doing what he is doing or for better tools with which to do it; and his research and plant development men are looking for new processes and new equipment to replace or alternate with existing ones.

There are three distinct sources of ideas for new processes and equipment.

1. There are, of course, ideas that originate within the company. Men who are constantly working on any product or line of products will naturally get new ideas for producing their products.

2. The technical literature, particularly current periodicals, will often suggest processes or new reactions to be tried out or equipment modifications to be considered.

3. Outside interests, either other technical organizations or, sometimes, an independent inventor, will suggest something new for consideration. From whatever source the new idea may come it must be carefully analyzed, its advantages and disadvantages weighed, and a decision

reached as to its value in comparison with that which is already in use.

We turn now to the investigations of the research and plant development departments on the finished products. In the first chapter we indicated that much of the work on these would be done by a separate unit, the products service department. However, there is also a large field of study on products that belongs to the research and plant development departments. In fact, all the work that these departments do on raw materials, processes, and equipment is, in the final analysis, for the purpose of improving the product, making it last longer, making it cheaper, or obtaining some other beneficial result. So in a sense everything we have said in this chapter has had a bearing on products. Furthermore, in order to be able to direct their efforts toward a uniform or an improved product, these departments must have before them a rather accurate picture of what the desirable qualities of the product are. They must learn not only what the physical and chemical characteristics are that make for a good product, but also the effect of variations in these

characteristics on the value of the finished product in use.

In all their studies of raw materials, processes, and equipment, the research and the plant development departments will direct their attention toward learning how they can maintain the desirable characteristics of the products involved, or even improve them. They will seek to give the product a better appearance, color, odor, feel, and so forth, and they will try to improve its performance through making it work faster or more thoroughly. If the product happens to be one that deteriorates with age, they will try to make it keep longer. They will work out proper storage and warehousing conditions, taking into account time, temperature, humidity, and other factors, just as they have to consider these in connection with raw materials.

They will work out proper containers, packages, and wrappers. This will involve studies of materials such as paper, cardboard, inks, adhesives, cans, bottles, and so on, and it will call for tests such as warehouse tests and trucking, shipping, and storage trials, together with in-

vestigations of the feasibility of shipping in bulk in tank cars or boxcars rather than in smaller containers.

The studies of the research and plant development departments will not be confined to the existing products. The workers in these groups will constantly be on the lookout for new products as well. Such new products may develop from various sources. For example, an existing product may be so modified that it is put on the market as a new brand. Such was the case when ordinary gasoline was transformed, by the addition of tetraethyl lead, into an antiknock gas. Again, a new product may be developed which will supplement an existing product. Such a case was the making of an automobile polish to be sold as an adjunct to the normal gas and oil business of a filling station. As another possibility, a new product may develop from the application in an entirely different field of some material which is currently being processed. For example, the petroleum industry introduced a brand-new line and entered a new merchandising field when it added to one of its distillates, which is a close

relative of gasoline and kerosene, an appropriate amount of pyrethrum extract, thereby producing a very effective fly spray.

Another source of ideas for new products comes through the working up of by-products. For example, the problem of still residues in the coal-tar industry led to the development both of a very satisfactory road material and of a good roofing.

Another phase of the work of the research and plant development departments on products has to do with their duplication of competitive products or the development of new products to compete with the competitive ones.

Having carried our investigational work from raw materials to finished products, we can now consider a few additional fields of work that are carried on in conjunction with those which we have already discussed.

The first of these is library work. It is fairly well known that the logical beginning of any study is to find out what, if anything, is already known on the subject, and the normal place to turn to find that out is to books. In a small company

every investigator will, of course, have to do his own library work and perhaps even supply his own library. In larger organizations, however, a library is usually maintained which contains books and periodicals pertinent to the industry. When such a library is provided it is often presided over by a technically trained librarian whose duties include the following:

1. To see that the library does contain the literature that is of value to the organization.

2. To read the literature dealing with the industry concerned and to be sure that the various members of the chemical staff see such books or articles as would be of help to them in their particular line of work.

3. To look up specific facts or lines of information for chemical division staff members. While it is, of course, obvious that any investigator will, himself, want to keep well abreast of the knowledge in his field, nevertheless there are frequently times when particular facts or lines of study need to be run down and it is often in the interest of efficiency to have one person who can do that sort of thing for the organization.

4. To save some of the wear and tear on the somewhat rusty French and German of staff members by doing a certain amount of translating for those who need that kind of help.

The second additional field we want to discuss is patent work. Naturally systematic investigation leads to patentable ideas, and it is important that these be properly taken care of. Hence in large organizations a patent department is maintained for that purpose. Its duties are:

1. To keep informed on patents, both foreign and domestic, that deal with matters of interest to the organization.

2. To call to the attention of the members of the chemical staff such patents as may be of interest to them.

3. To prepare and file applications for patents on ideas developed within the company.

4. To follow up these applications with the Patent Office, studying the office actions that are taken on the various applications, preparing and filing proofs of invention, and preparing suitable amendments in line with the Patent Office requirements.

5. To supply the technical aid necessary in patent suits.

One may wonder from the foregoing whether this job is one for a chemist or a lawyer, and the answer, of course, is that the man who handles the job successfully must be something of both.

The third additional field of work spreads itself over many other fields. It is the selection or development of proper analytical methods. We have already had quite a lot to say about analytical chemistry, much of it very discouraging, but the subject we are about to take up here is vitally important to successful manufacture. While the control laboratories and the standards department are responsible for actually doing the analytical work, the research department is the one primarily responsible for developing the proper analytical methods.

Suitable analytical methods must be chosen to evaluate raw materials, control the processes, and assure the quality of the products, but because such analytical work is a direct charge on manufacture it must not be allowed to cost any more money than is necessary. Consequently short cuts

must be developed where possible. Analyses must be put on a production basis. When feasible, advantage must be taken of such rapid measuring instruments as the microscope, the refractometer, or the spectroscope. Often special machines can be developed to promote speed and economy.

In addition to the control analyses, most large manufacturers run "accounting analyses." As suggested by their name, these are for the purpose of keeping proper accounts of materials. In other words, they help the cost department to maintain a "material balance," just as you or I keep a bank balance, or try to at least.

Still other analytical work often is necessary in following current research or plant development problems. Sometimes known methods can be adapted to this, but often entirely new ones have to be worked out. Inasmuch as the research in question is to be interpreted or evaluated in terms of the analyses made, it is, of course, essential that the analytical work be properly done. Because the analyses on investigational work often are not of a kind that can advantageously be done by the "lab boys" who do routine work,

they are carried out to best advantage by analysts of a higher degree of skill, working directly in the research department.

There is always a certain amount of work to be done in standardizing the analytical methods in use in one's own plant with those of outside agencies, such as the government laboratories, technical societies, suppliers of raw materials, customers, and others. Purchases or sales may be involved, or it may be merely some cooperative work for the sake of a better understanding in some industry, but, whatever it is, it calls for painstaking technique. Here again an analyst with really good chemical training is essential.

Another analytical problem which frequently comes to the fore is that of developing a means of expressing intangibles, such as color, odor, consistency, and so on, in numerical terms. We can argue interminably about some of these things because they are matters of personal opinion or do not lend themselves to being accurately described. You and I can agree today, perhaps, as to which of two objects is the whiter, but how shall we record our findings so someone else may

know a year from now how white was the white we saw? When we can learn enough about some of these factors to be able to report them in measurable units we add another valuable tool to successful manufacture.

A final field of the research worker is a sort of catch-as-catch-can one. You may be surprised to find it included as part of the job, yet sooner or later it bobs up in practically every company. It involves doing all sorts of odd chores for individuals within the organization, and it may range all the way from learning something of the mineral content of the unparalleled water that flows from a hidden spring at the vice-president's summer home to prescribing a treatment to rid the sales manager's swimming pool of objectionable algae. Or some member of the organization may be elected to his village water board, and you may have to help him work out a suitable water-softening plant for his community. It is clear, of course, that work of this sort doesn't make much money for the company, but it is a type of service that it is sometimes better to render than refuse.

The ultimate in this sort of work that ever came to the writer's attention was a request from a purchasing agent who had remained a bachelor for many, many crusty years and then finally took unto himself a wife. The pent-up romance of all his solitary life burst forth in the sentimental request that the laboratory take the orchids that his bride had worn and preserve them in some effective manner so that they could be handed on to posterity, if any. And that from a purchasing agent!

We are reaching the close of our chapter on research and plant development. Logically, we should sum up what we have had to say in a few concise sentences. But when we try to do that we find ourselves balked by the fact that the territory covered has been so broad it doesn't want to condense. Let us not try it. Let us leave the subject with the observation that the "studious inquiry" with which the research and plant development departments concern themselves leads into every crevice and cranny of the manufacturing picture.

Chapter IV

PRODUCTS SERVICE

Now some of us call on the customer to find out what he wants.

Traveling chemists.
Bum! Bum!
Inquiring chemists.

And some ot us run complaints down, bearding kickers in their haunts.

Unraveling chemists.
Bum! Bum!
Perspiring chemists.

Some explain our wares in our salesmen's schools so those boys will be wise,
And some of us try to work out new ideas to advertise
So folks will buy from us instead of from the other guys.

But we're chemists.
Bum! Bum!
We're the chemists.

After all is said and done, a business thrives and grows, if it does, because of one class of people—its customers. To be sure, good equipment, efficient manufacturing technique, and skilled personnel contribute to the production of goods that attract buyers, but it is the buyers

themselves who supply the money to improve factories, to buy better equipment, to pay wages, and to disburse dividends. With the realization of the importance of the customer it becomes clear that a fairly careful study of his likes and dislikes is in order. To gather information concerning this all-important person and to help devise means to serve him better is the function of the products service department.

Obviously if we are to learn anything about a customer's reaction toward our products we have to develop his point of view and appreciate his problems. The surest way to do this is to use our products in the same way and for the same purposes as he uses them. Thus, if we are selling the laundry trade, for example, we shall do well to study the laundering processes, to learn the principles involved in successful laundering, to learn the effect of various cleansing materials, to develop the very best practices for meeting certain specific conditions. In fact, we shall apply to the laundry the very same principles which we discussed in Chaps. II and III as applying to our own business. This means we shall make laboratory,

semiplant-scale, and full-plant-scale studies of the laundering process. In other words we shall go into the problems of our customers so thoroughly that we shall be qualified to serve as a consulting laboratory to those industries that use our products.

If an organization is to be prepared to serve in the capacity indicated above two things are necessary. In the first place, technical men have to be put in a position to meet the customers. They have to "come out of the kitchen," put on their Sunday suits, and circulate in the trade more or less as if they were bona fide, garden-variety traveling men. In the second place, these men must have a sufficiently good technical background to be able to do for the industries they visit substantially the same sort of work that our research and plant development men do for our own industry. Of course their major attention is devoted to that portion of the industry to which they are selling which concerns itself with our products, but they cannot stop there. They must be ready, if necessary, to undertake work on other raw materials used by the industry, on

equipment, processes, packaging material, in fact anything that may come up. There are, of course, practical limits to how far they are justified in working on problems not immediately connected with their own products, and someone may well ask why they should spend any time at all on problems other than those dealing with the use of their own commodities. To that question there are several answers.

In the first place, there cannot be a proper understanding of the requirements of our product unless there is some knowledge of the related problems.

In the second place, if a complaint on our product arises it is not enough to assure a customer that we have checked the quality of our material, that we have found it satisfactory, and that his difficulty therefore must lie elsewhere. We are in a much better position if, in addition to reassuring the customer about our product, we are able to help him locate the actual cause of his trouble.

In the third place, this more thorough knowledge of the customer's problems may lead to the discovery of new uses for our products, uses in

phases of the customer's work other than the ones in which he happens to be using our products at the moment. Or we may find a problem that can be solved by the development of a new product. An example that illustrates this last point is the introduction a few years ago of a new shortening to the baking industry. For a long time practically everyone had recognized that bakers' cakes did not taste so good as housewives' cakes, but no one ever did much about it except to urge the baker to make better ones. Comprehensive instructions, or even pertinent suggestions, on how he was to do it were lacking. In fact, no one knew exactly why bakers' cakes were different. Then a real study of the matter was undertaken by a group of chemically trained men. The first thing they did was to take an almost endless number of household cake recipes, to classify them, and then, so they could be compared with bakers' formulas, to convert them from cupfuls, teaspoonfuls, pinches, and so forth, to pounds and ounces. The result was a revelation. No wonder the bakers' cakes and those of the housewife did not taste alike. Below is a typical com-

parison of homemade cake and old-style baker's cake, both calculated on the basis of 100 lb. of flour. It will be noticed that, where the housewife uses sugar in the ratio of 118 to 100 lb. of flour, the baker used only 90. Similarly, where the housewife used 55 eggs the baker used only 42. Corresponding differences may be noticed in the other materials. You would not expect cakes made from such different proportions of ingredients to be very much alike, would you?

Ingredients	Old-fashioned baker's cake, pounds	Homemade cake, pounds
Flour	100	100
Sugar	90	118
Eggs	42	55
Milk	58	66
Shortening	35	48
Salt	2½	2½
Baking powder	3	4

The next logical step was to make up a baker's formula patterned after that of the housewife. When this was done, however, the result was a sad one. The cake mixed on the machinery that the baker used "fell" and was wholly inedible.

Yet to maintain production he had to work on a large scale, and it was his machinery which enabled him to do so. To make a long story short, a shortening was developed that enabled the baker to use proportions of ingredients comparable to those in the housewife's own recipes and yet to employ his machinery to produce cakes in quantity. Thus a new product, developed as a result of chemists' studies of customers' needs, has revolutionized the established practices of an entire industry.

Next we turn to a phase of the products service department's activity quite different from the foregoing. The familiarity with the customers' requirements previously discussed furnishes the background for a testing unit that may be designated as a "quality-control unit." We learned in our chapter on "Standards" of the careful analytical control exercised in a modern factory to maintain a uniformly high quality. But that control is based on certain analytical measurements. As a check on that, the quality control unit of the products service department inspects and uses samples of the various products

in the same way the ultimate consumer will use them. For example, if it is a shortening that is being manufactured, actual baking tests will be run with a sample of every batch made, just to be sure that in the hands of a baker the shortening will behave as he will expect it to.

Again, an alert manufacturer is interested not only in his own products, but in those of his competitor as well. For this reason he will have his quality-control unit follow systematically the products of his competitors. Such a study may serve two purposes. If the competitive product is better in some respect, the necessity for improving his own product in that direction becomes apparent. If the competitive product is poorer, a potential "talking point" has been uncovered for his sales department.

Complaints, improperly handled, almost invariably lose a customer. Properly dealt with they may not only hold him, but may even build substantial good will. As a result, one of the important problems of a products service department is the efficient handling of complaints. We have already touched on the fact that it is not enough

just to deny that our product was at fault; it is necessary, in addition, to locate the real cause and explain to the customer's satisfaction that the complaint against us was unjustified. Unfortunately, however, even in the best of manufacturing concerns, complaints may sometimes be justified and when they are it is up to the products service department to analyze their cause and to see to it that the unfavorable conditions that were responsible are corrected. A complaint is often a straw showing which way the wind is blowing, and every one is deserving of intelligent attention.

Because of the background that contact with the trade gives and the knowledge of performance that comes from constant usage study of products, several other opportunities for a products service department become apparent. We have already hinted at the fact that this work may be of direct help in sales and advertising. This is true because the products service department is in the position of knowing not only the customer's needs, but the capacity of our products and our competitors'

products to meet those needs. For this reason this department can develop sales and advertising points that might otherwise be missed. Of course, in this enlightened day and age, there are a good many sales and advertising points which, we are happy to say, the chemist had no hand in developing. Even in connection with these, however, he may be of some use, for if a competing company has made some outlandish claims for its product, our chemists, knowing what the product will really do, can sometimes develop effective refutation. Thus suitable information can be given to salesmen to aid them in helping their customers see the fallacies of the statements that competitors may be making.

Our own advertising copy can also be advantageously reviewed by the products service department for several reasons.

1. Technical inaccuracies may be caught and called to the attention of the advertising department so that they can keep their stories in line with the facts. Of course, as suggested before, there are some advertising departments that do

not appreciate help of this sort. Some of them seem to prefer to take the point of view that when the virtues extolled by the printed page far exceed the performance of the product in question, it is not the advertising that is at fault at all. They prefer to argue that the advertising is really splendid, that the merchandise is at fault because it will not do the things the advertising says it will. However, advertising departments these days are, for the most part, quite willing to enlist the chemist's aid in fact finding.

2. Statements which may be irritating to our customers may be avoided. For example, a company selling soaps to both housewives and laundries should not let its household advertising be of such a nature as to reflect on the quality of work done by the commercial laundry, for if it does that company's commercial-laundry customers will let themselves be heard from with vim, vigor, and diminution of orders. Of course, the sales and advertising people themselves are watching this point, but the familiarity the products service department gains with the customer's point of view often enables this

department to sense difficulties that others might overlook.

Our own and competitive advertising are not the only forms of printed material we must watch. Outside agencies occasionally make statements which have a bearing on our business and which need correcting if they are inaccurate.

There is the case of the learned (?) health authority (?!) who used the columns of a metropolitan daily paper to warn people that a plague of goiters was just around the corner. He based this alarming prophecy on the following line of reasoning: (1) Goiter is likely to result if the diet is deficient in iodine. (2) Hydrogenated shortenings, which are being consumed in large quantities, are made from oil, the hydrogenation of which has resulted in a lowering of the iodine value. (3) Certainly the wide use of an oil or fat that had had its iodine value reduced would bring on an increasing number of cases of goiter, if not a positive epidemic.

In case the foregoing should by any chance be read by anyone who is not somewhat conversant with chemistry, let us hasten to explain that the

iodine value of a fat has nothing to do with the amount of iodine it may or may not contain. As a matter of fact, fats or oils do not *contain* iodine. The iodine value is an analytical measure of certain characteristics of the oil, a fact which is familiar to thousands of students who have taken chemistry in college but about which the pseudo health expert had never heard.

An equally sensible theory concerning the digestibility of edible fats was once expounded in a book that had a wide sale. According to this book certain fats, when used for deep frying, become indigestible because portions of the fat boil off, leaving behind them other portions that have a boiling point too high to permit them to boil away. In the course of time so much of this high-boiling-point fat accumulates in this way that the frying fat becomes terribly indigestible. The chief trouble with this story is that it is untrue. As anyone knows who really knows anything at all about the fats used for deep frying, such fats do not boil at all; hence the idea that a portion of them boils away becomes recognizable as sheer nonsense.

Other forms of help that a products service department can give to the sales and advertising departments include:

1. Writing instructions for the use of products.

2. Conducting correspondence with customers, with allied trade groups, and with various technical groups along lines that help distribute general information about products.

3. Preparing convention displays of a more or less technical nature.

4. Giving talks before trade conventions and technical society meetings.

5. Preparing bulletins and booklets of a publicity or advertising nature. These may be highly technical, directed at scientifically minded readers, or they may be so written as to be informative to the layman.

6. Conducting schools for salesmen, to inform them about the desirable qualities of the products they sell and to give them information concerning the uses of the products.

Another use for a products service department arises when the research department develops an improvement in one of the company's products or

when some outside agency, either an inventive individual or an industrial concern, offers the company some new product to manufacture and sell. In such cases the products service department is in a good position to evaluate the improvement or the new product in terms of how it will appeal to customers and to help to decide whether to adopt it or reject it.

If you have begun to wonder at this point whether we are still talking about a chemist we might ask in reply, "Why not?" Is there any reason why these various jobs that deal with facts about things should not be handled by a man who has spent time training himself in learning to evaluate facts and in making a study of what these things really are, how they behave, and how they can be made to behave differently if necessary? Is there any reason why the chemist should pass his findings out through the laboratory door and let someone on the outside interpret them? Can he not go along with his facts and bring the benefit of his familiarity with them to their ultimate application?

Chemistry need not be a chain holding a man in a laboratory where he works out answers for Tom, Dick, and Harry on the outside to take and make use of. Chemistry should be a tool which a man uses as a supplement to other capabilities and which thus enables him to meet Tom, Dick, and Harry, in any corner of industry or commerce, and help all three of them to do a better job than they had been able to do before the tool of chemistry was brought to their attention.

Chapter V

THE KIND OF CHEMISTS INDUSTRY WANTS

We're a hopeful group of students setting out to find some jobs.
We want to be chemists.
Bum! Bum!
We want to be chemists
We would like to have our money come in gobs 'n' gobs 'n' gobs—
If that happens to chemists.
Bum! Bum!
If that happens to chemists.
There are some of us who made the highest grades in all the class,
And some of us were happy if we managed just to pass,
But bright or dumb, commercially we're all as green as grass,
But we want to be chemists.
Bum! Bum!
We want to be chemists.

It would be much easier to discuss what kind of chemists industry wants if we were sure at this point that we all agreed on the answer to the major question propounded in our first chapter, namely, What is a chemist? But I don't suppose

all of us ever will think exactly the same about that question. Some people, as we have suggested before, see a tired-looking soul who makes umpty-ump dozen polarimeter readings a day, more or less, in somebody's beet-sugar factory and they speak of him as being not just that factory's "chemist," but perhaps its "chief chemist."

Other people will know a somewhat frowsy being who shows unmistakable signs of being not altogether housebroken socially, and, because in his waking hours he is a denizen of some disordered laboratory, they classify him in their minds as a chemist.

Neither of these types, however, quite represents the person we are about to consider. The man we propose to discuss here is the one who has had a college training in chemistry or chemical engineering and who either is about to start to work on his first job or else has been out of school only a few years, perhaps in commercial work or maybe in teaching, and is contemplating a new connection in industrial work.

One way of starting our discussion about the kind of chemists industry wants is to consider

some of the questions that are asked of candidates by those men who do the scouting work for large employers. Whether or not such "scouts" know what they are doing may still be an open question, but the fact remains that when they sniff around a college class of twenty or more individuals and pick out the two or three they think are best suited to the needs of their particular organizations, they do their picking largely on the kind of answers they get to their questioning.

Oddly enough these men, who come to our educational institutions announcing that they are interested in hiring some chemists, are not, as a matter of fact, looking for chemists at all. Rather they are looking for a type of man. To be sure, they want the men they seek to have a chemical or a chemical engineering training, but, more important, they want him to be the right sort of an individual. They want him not only to be capable of doing the job they have in mind for him to start on, but they want him to be able to keep growing to meet additional responsibilities as they come his way. If possible, they want him to be the kind of person who will never find

himself against a stone wall, so far as promotions are concerned, either because of lack of capacity or because of some personal shortcoming. This being the object of their search, what sort of questions do they put to him?

One of the first and most important things they ask is, "What kind of a student have you been?" or "What sort of a scholastic record have you made?" They believe they want a high type of intelligence and they think that ordinarily a man with such intelligence will have made a good scholastic record. If the student can answer that he has made mostly A's and B's with maybe only an occasional C, that is a good sign. If he can say he was in the top 5 or 10 per cent of his class, that is a healthy indication. If he has been able to rate No. 1 in his class, that registers mighty heavily in his favor. If he was only average, he is still not out of the running, of course, but he is going to have to show some other highly desirable characteristics to compensate for his lack of scholastic leadership. And if his grades averaged below C, well, he may, in later life, develop to be the Pud'n'head Jones whose career

is sometimes cited as proof that the boys who are dumbbells in school succeed in a bigger way and go further when they get out into the world than do the bright boys, but he is going to have a tough time getting a good connection with a large and progressive organization to start with. Brains count. There is no doubt of it, and the best way industry has of finding out whether the prospective candidate for a job has them is by his scholastic record.

Somebody is probably wondering by this time why the *student* is asked about this. Why are not his professors questioned concerning him, or, better yet, why is not a record of his grades looked up? No doubt, if the mere facts were all one wanted to know, that would be the way to get them and, of course, the professors will be asked for their opinions and the records may be reviewed. But by asking the student himself two things are accomplished.

First, the facts about his scholastic standing are brought to light fairly accurately. Only very rarely will a man overstate his attainments on such an occasion. In fact, there is usually more trouble in

getting a fair answer to this question because of the modesty of the student than because of any tendency on his part to overrate himself.

Second, some insight is gained into the student's personal characteristics. The question, directly put, is not an easy one to answer, and the interviewer has an opportunity to see how the man being interviewed meets an unusual situation.

There are many different reactions to the question. Those individuals who are less keen do not see what the questioner is driving at. They just look blank, become confused, and their answers come in a stumbling fashion. Those who are quick to sense what is wanted are faced with the problem of telling how good they are without appearing obnoxiously "cocky" or of outlining what their shortcomings have been in a manner that will not make them lose out entirely. The candidate's response to either situation is quite likely to give some interesting insight into his characteristics.

Another question is likely to be something along this line. "What did you do around school besides get your lessons?" The answer the inter-

viewer hopes to get is that the candidate was a class officer or one of the editors of the school annual or a member of the football team or an active participant in the dramatic club or the glee club or anything that shows he lived the life of the school. Industry wants men who are interested in their environment, who want to do things with their fellows, who are alive to what is going on about them. It does not want the ingrown soul who craves seclusion and who cannot put himself into the life of which he is a part.

If the answer to this question can be that the candidate was president of this or captain of that or business manager of the other, so much the better, for, while those jobs sometimes go to the man who is willing to be a party to questionable campus politics, they more often go to the man who has a natural capacity for leadership and that, of course, is another faculty which industry wants.

Sometimes the answer to the question is, "I had to earn money and had no time for anything but that and my lessons." This is not a very good excuse. It is usually possible to earn money and

to take at least some part in the activities of the school.

It sometimes happens that a professor overhears this question and interjects a remark to the effect that he works his students so hard in his department or in his classes that they have no time for anything else but their studies; and he rather preens himself as he says it. Well, those gentlemen may be developing their students to be well-informed chemists or chemical engineers, but they are not helping, by such a point of view, to develop their students into what industry wants in the way of men. No doubt many of their students are succeeding, but it is probably in spite of the grind they have been through, not because of it. Of course, anyone who knows anything about the requirements of a training in chemistry knows that plenty of hard work is required, and no one expects such a course to smack of supervised play. On the other hand, however, it would seem that industrial chemistry can be administered to students in such a way that they can "live" and learn at the same time.

Another question often asked is, "What have you done during your vacations while you have been coming along through school?" All too often the candidate hangs his head and mumbles in shame that he never had a job of a chemical nature, and then stops as if that were the answer to the question. But it is not—far from it. No one cares much whether a recent graduate ever had a job of a chemical nature. He is not being hired as an experienced man and what little he could learn of chemical practice during the few summers he has had to get experience would not be worth such a great deal anyhow. The most important thing is, did he work? Of course, there are other things he could do that would help round out his background. Travel, for example, is worth while, but the interviewer would feel surer that the man had learned about working if he had worked his way on his travels.

Sometimes the reply has to be that the candidate went home and helped on the farm. That is not a bad answer. He did not learn much about chemical equipment, but he had to keep the mowing machine in shape and the tractor going,

and, after a few summers at that, he at least will not shy at a monkey wrench or require a special set of mimeographed instructions to prompt him to fix a piece of equipment if it happens to go wrong.

Sometimes a boy has sold books or aluminum ware or something else. If he did, he learned how to meet people, he learned to judge how they were going to react under certain conditions, and he learned how to treat them so that they would react favorably to what he was presenting to them. That is a kind of training that chemists, as a class, probably need as much as any other single sort of experience. The folks these chemists-in-training are going to work with later are very much the same sort of souls the boys would meet in summer selling, and what the young men learn in dealing with these people is going to stand them in good stead the rest of their lives.

The more varied the experience a student can get during those precious summers the better, but let it never worry anyone that during his summer vacations he did not happen to be able to get a chemical job.

And now for a question which is not ordinarily asked of a candidate but the answer to which usually has almost as much to do with the young chemist's success in a large organization as any other single thing: Can you express yourself readily, especially in writing?

If the truthful answer to that question is not "Yes," the aspiring young gentleman under consideration had better dig in with all his might and main and get himself in such shape that the answer does not have to be "No." Straight thinking is probably the most essential single thing in one's bag of tricks, but the ability to express oneself well comes a mighty close second.

Perhaps there are some people who are not going to accept this thought right away, but let us call to their attention the following points: Practically from the beginning of his industrial career the chemist is going to be writing reports and letters concerning his work. He will be trying to explain what he did, why he did it, and what results he got. He will be undertaking to marshal his facts in such a way that readers will be led to the same conclusion he has reached. Now he will come in

contact with relatively few people if he joins a large organization, and his immediate boss will be the only one he can impress with how good he really is (assuming, for the moment, that he is good). But his reports and letters lead a different life. They go through his boss's hands to others above him, and, if a man's report is a really good one on an important subject, it will fall into the hands of people whom he personally has little or no opportunity to see (or more important, to be seen by). Well-written reports mean circulating good impressions of the writer. Poorly written ones either do not get far enough to circulate any impressions or, if they do, they circulate poor ones, and, you know, if you can't be the boss's son or marry his daughter, it's up to you to get favorable attention by inducing people to think well of you.

When we started discussing this particular question we mentioned the fact that it was one that is not generally asked of the student himself. The reason is that usually it would be a foregone conclusion that he would answer "Yes," whereas, in truth and in fact, as the lawyers say, that is the

wrong answer in many cases. And, strangely enough, the question of the man's honesty has nothing to do with the matter. For some strange reason most people appear to be under the impression that what they write is pretty good whether it actually is or not.

Of course, the background for a good report is good work and without it there can be no good report. But at the risk of being boresome, or even irritating, let us urge once more that every ambitious embryonic chemist should be sure to train himself so that, if he does a good job, he can tell about it well.

So much for the questions; here are a few additional points.

While we are on the subject of making favorable impressions, we might say a word or two about the matter of personal appearance, delicate though the subject may be. What we intend to say about it you have no doubt guessed already—it is obvious. A neat appearance is an asset. Dirty fingernails, a couple of days' growth of beard, a shock of hair that needed cutting two weeks ago and still does, all are liabilities. Many an honest

heart may beat beneath a ragged vest, but everybody would feel better about it if the vest were not ragged.

Curiously enough, while all the foregoing is recognized and understood by practically everyone, there are many who seem to feel that for the technical man it does not quite apply. They apparently think the rules are suspended as far as he is concerned, and there is, in some quarters, even a rather well-defined impression that he has to look a bit grubby to prove he is the stuff of which technical men are made. One employer once refused to hire a student recommended to him by a certain professor because the student looked dirty and uncouth, all of which led the good professor to inquire whether industry expected him to run a beauty parlor along with his course in chemistry. People may let themselves look grubby for either one of two reasons. It may be that they do not know any better and that they will learn to polish themselves up a little more thoroughly later on. Or it may be that they just don't give a hoot. If it is the former, one might put up with them until they learned better. But if

it is the latter, there is not much hope, and the man who is interviewing prospects cannot always be sure which kind he is dealing with. A clean face and a neat appearance will relieve the interviewer of the necessity of wondering. The chemist-to-be can make up his mind to one thing. If he is going to insist on indulging himself in the joys of being unkempt and seedy-looking, it is probably going to cost him money. Maybe he can afford it, but certainly he should understand that it is a luxury.

Since it is men that industry wants, rather than merely chemists, someone is probably wondering why character references are not the first thing investigated. Well, sooner or later they are considered, but as a matter of fact that side of the question takes care of itself almost automatically. In the first place, the men in the schools where chemists are trained are usually men of character themselves, and it is very doubtful whether an instructor would let a man who was not all right go to an employer without giving the employer the facts about him. In the second place, men who go in for a scientific training

apparently are the kind whose characters, for the most part, are made of fairly sound stuff. Whatever the reason may be, the fact remains that among the technically trained men who have come under the writer's observation, those who were not of good character have been few and far between. Understand, the words "chemist" and "angel" are not synonymous, but the moral fiber of the technically trained as a class seems to be pretty good.

A while ago we mentioned the advantages of work during summer vacations as a partial training for industrial work. What other forms of preparation are helpful?

A certain amount of experience as a teacher seems to make for success. It is valuable for two reasons. First, as is well known though not always admitted, a teacher usually learns more from a course than the students. At least, by the time a course has been taught a number of times, the one teaching it usually has the subject matter pretty well in hand. In this way teaching experience grinds the facts of chemistry into the mind in a way that simply taking the courses cannot

do. Second, the scientist knows, or comes to know in the course of time, a lot of facts of a more or less technical nature, which other people in the organization in which he works do not know but which they should learn. The teacher is accustomed to getting ideas across to people who are not familiar with what he is telling them. He knows how to start at the proper level of understanding so his hearers will be with him, and then how to build up his thought structure in a logical and understandable way. To industrial work he brings this same ability to make his points clear.

On the other hand, too much teaching sometimes develops a frame of mind that takes for granted that the party of the first part is to be accepted as the final authority on all occasions and—well, you know how some of them get. That would be fatal in industry.

What course of study should the man preparing for an industrial career have had? Ah, many wise men have asked each other that question and then held learned conferences trying to decide on what the answer was. Fools may rush in where

angels fear to tread, but the writer of these words is not going to undertake to answer the question. He will, however, offer a few comments.

Obviously the fundamental courses of inorganic, organic, analytical, and physical chemistry, together with a thorough course in physics, are the foundation on which to build. The elementary courses in these subjects should be supplemented with advanced and more thorough courses in each of these fields. But what more?

Some knowledge of biological chemistry and bacteriology might well be included as a valuable part of the training program.

We have already pointed out the important role which the ability to express oneself plays in a person's progress. We have called attention to the fact that one is reporting on his work constantly, either orally or in writing, from the day he starts his job to the day he is fired, or, more happily, to the day he retires. Too often there is not enough attention paid to this phase of a student's training.

What about mathematics? How much of that ought one have? Well, there is another contro-

versial subject. Anyone who expresses himself very strongly on the matter is sticking his chin out, and that is always dangerous. But again, some observations may not be out of order. Personally, I have yet to meet, in industrial work, and I include here the fundamental research necessary in connection with industrial work, more than a handful of men who ever had any occasion to use calculus—and I suspect one or two of those who did use it did so for the very profound effect it was supposed to have on the men who saw them spreading integration signs around. The fact that it is used so infrequently might lead some people to feel it is an unnecessary subject. Such a conclusion, however, would seem questionable for it does have its definite place, but it should not be emphasized out of proportion to its importance. As between learning to write and learning to integrate, the former is definitely the more useful.

What about engineering training for the industrial chemist? In other words, shall the student contemplating a future in industry study chemistry or chemical engineering? That is another widely

debated question and the subject of pretty lively controversy between the chemistry and engineering departments of every educational institution large enough to harbor both factions. The participants in discussions of the subject are usually too gentlemanly to say what they really think, but, comrades, how they think!

Once upon a time I tried to get some reliable information on the subject by going to one of the largest universities in the country and asking the head of the chemistry department how the training he gave his men differed from that given by the department of chemical engineering. He explained that he taught his men chemistry. They knew the fundamental facts. They understood the controlling conditions. They were equipped to do the thinking for industry. The chemical engineers, on the other hand, were simply taught the mechanics of handling chemical materials. They could run the pumps and stills and filter presses and whatnots under instructions from the chemists.

Then I went to the head of the department of chemical engineering at the same institution and

asked him how the training he gave his men differed from that given by the department of chemistry. His answer was very simple. "We teach our men all the chemistry they give students over in the chemistry department, and in addition we teach them how to get things done." It was all on a very high plane, you understand, but it rather discourages one from making further studies into the subject. As a matter of fact, one of the most capable industrial chemists I have ever seen in action was trained as an "agricultural chemist."

Probably the interest and aptitude of the individual will have more to do with his fitness for one line of work or another than the training which is given him. Some men enjoy working with machinery—actually operating it, taking it apart, improving it. Such men make good plant development chemists whether they have an engineering training or not. Other men have an aversion to machinery. While they may understand how it works, it bores them actually to have to work it. All the engineering training in the world would not make them first-class plant

development men. Usually men of the first type are attracted to courses in chemical engineering, but if they happen to take chemistry instead they are still good men for plant development work. Fortunately the field of industrial chemistry is broad enough to offer a place for individuals of both types.

What of graduate work? Beneficial? Indispensable?

In university circles there is practically only one answer to the question of the value of graduate work that is considered sound. The keener and more alert student is advised by his teachers to take additional work by all means. In fact, there are university professors who become almost savage toward an employer who comes within their halls seeking to hire the exceptionally bright student when he has taken only his bachelor's degree. It is wrong, according to them, because such a student should go on for his Ph.D.

If all that industry wanted of men with chemical training was investigational work these professors would have much excellent argument on their side. But, as we have seen in previous

chapters, that is not all industry does want. Consequently we cannot agree with them entirely. There is something to be said on both sides of the question.

The graduate student frequently devotes part of his time to teaching while progressing with his graduate studies and in this way he gains for himself the advantages that were pointed out in our previous discussion of teaching. On the other hand, the student who does not stay for graduate work gets a head start in becoming familiar with the work of the industry in which he is to launch out and a head start in working with the people with whom he is eventually to be associated. He will have gained a certain number of years of seniority.

Again, the additional training which graduate work gives, particularly the practice gained in attacking investigational work, makes for resourcefulness, develops the imagination, and tends to remove the "lost" feeling that sometimes overwhelms the beginner on his first job of facing unknown conditions and of having to bring an answer out of the darkness into the light. But

against that, the point may be made that industry, too, offers plenty of practice in attacking investigational problems, and its problems, usually being practical ones of immediate interest, often seem more stimulating than those offered the advanced worker in a university.

A further advantage in remaining in school for graduate work is that it enables the student to enjoy much more intimate contact with the older and more experienced members of the faculty than the undergraduate student is able to have, and there is no denying that much is gained through this closer association with the men who are devoting their lives to the fundamentals of their science. But industry too has its "teachers," who can and do do much in broadening the knowledge of the "apprentice" investigators who come within the circle of their influence.

It can be cited, and sometimes is, by heads of chemistry departments that a larger percentage of their Ph.D. men succeed than of their M.S. men, and that a greater proportion of these, in turn, do well than of the bachelor-degree men.

However, this is not fair evidence on the case, and it certainly is not scientific evidence. Of course, more graduate-degree men succeed proportionately. They were only allowed to stay on for graduate work because they represented the more promising portion of their class.

Perhaps we can round out this discussion with the observation that in no field of industrial work is graduate training absolutely necessary, and the student who will force himself, at the expense of health or even disposition, to endure several years of what to him is drudgery, just to end up by being one day dubbed "Doctor," is making a mistake. If he is continuing his graduate study because somebody has told him he ought to, instead of because of his own keen interest in it, then for him it is probably not worth continuing. And as for the "Doctor," the chances are that he will be reduced to the dead level of "Doc" anyhow when he gets out, because that is the convenient handle put on most chemists by their nontechnical coworkers in industry, whether they have actually had graduate work or whether they are just plain beaker boys who never even went to college.

On the other hand, if a student taking his bachelor's degree has a genuine interest in further study and has a chance to go on for advanced work, he certainly will make no mistake in taking advantage of the opportunity. But, let us repeat, he should have a genuine interest in continuing, not a forced one.

One man in industry who had achieved at least some degree of success in his field summed up a discussion on the subject of graduate work about as follows: "I chose to remain in school for graduate work till I had satisfied the requirements for a Ph.D. and I am glad I did. On the other hand, I work for a chemist who did not take a Ph.D., and he works for a chemist who did not take a Ph.D., and he works for a man who didn't even go to college." All of which probably is some indication as to whether graduate work is essential to the success of a chemist in industry.

Chapter VI

THE KIND OF INDUSTRIES CHEMISTS WANT

We're an assorted bunch of industries that make this country's wealth.
We hire chemists.
Bum! Bum!
We hire chemists.
And, sometimes, when they fail to help our economic health,
We fire chemists.
Bum! Bum!
We fire chemists.
Now some of us need the chemists' aid in a serious, vital way,
Others might do without them, but we're pretty sure they pay,
While some of us simply keep them, but just why we couldn't say.
But we have chemists.
Bum! Bum!
We hire chemists.

When years of business depression hit the country it is probably quite out of order to raise any question as to what kind of industries chemists

want to work for. By and large the answer to the question, at such times, has to be, "Any kind that will have us." Consequently in such periods some of us lay our chemical training on the shelf, for the time being, and go to driving taxicabs or selling sandwiches as expedient, if not particularly lucrative or inspiring, occupations. However, better times always seem to come again when we have some choice as to what we shall do. Consequently we venture to put in a few words concerning the factors to be considered in making a choice.

Before we can intelligently discuss the subject of the relative merits of various industries, however, we have to decide just what we want the industry that employs us to do for us.

As a starting minimum, of course, we want it to pay us a living wage, but actually almost any industry, if it will have us at all, will do that; so suppose we take that much for granted and go on to say that we want it to hold out an opportunity for a good deal more than a living wage.

We want it to offer a "saving wage," which means not only enough to live on, but enough to

enable us to enjoy some of the worth-while things life has to offer and, in addition, enough to permit us to lay by a proper surplus. We think we would like to receive this surplus over our actual needs so that we can put some of it away and one day have a supply of money in addition to our salary coming into our coffers.

Finally, it is probable that most of us look forward to the day when we shall have saved enough so that we shall be able to be more or less independent of our salaries. Not, mind you, that, having achieved such independence, we shall want to stop working. We realize that only by keeping reasonably active can we actually remain contented and we recognize that some of the hardest working men many of us know are ones who work from choice, not necessity. But understanding all that, we still think, many of us at least, that it is going to be a soul-satisfying experience to see our independent income grow to a point where we can get along without our salaries if necessary.

In addition to a "saving" income, we want to feel reasonably sure of a continuance of our job, assuming, of course, that we do acceptable work

on it. We do not like a situation such that a whim of some official or heavy stockholder may result in all chemical division activity being suddenly suspended, with the resultant calamity of our being thrown out of our jobs. We want to feel that chemical help is sufficiently vital to our employer to make him hesitate about discontinuing it, or even curtailing it too drastically.

Now we come to a point which many people will say should have been the first and foremost of all, and perhaps it should, though to some of the rest of us it would not begin to register in importance until the points previously mentioned were properly covered. We refer to having interesting and stimulating work in congenial surroundings. This point is, of course, of tremendous importance, but the reason for not putting it first is that almost any work becomes interesting and stimulating if we throw ourselves into it and if we realize that it is getting us somewhere.

But what does it mean to be "getting somewhere"? Well, as we said before, we want to be gaining financially, and that is part of it. But we also want to be growing in the esteem of our

coworkers and our superiors. The niche which we occupy in industry may be a minor or inconspicuous one, but we do want those of our fellow men with whom we come in contact to respect what we know about our little segment of the world's work and to think well of the way we handle our job. (All of which, of course, assumes that we are doing a good piece of work in our field.)

Speaking of esteem and our relative place in the general scheme of things, it may be of interest to refer to an experience that a certain man once had when calling on a large industrial concern where he wanted to discuss a technical problem with the company's chief chemist. As one would do in such a case, he went to the main office and announced that he would like to see Dr. Blank. The lady at the reception desk eyed him with suspicion. "What are you selling?" she asked. In simple words of not over one or two syllables he informed her that he had nothing to sell, that he was connected with an industry wholly unrelated to the one on which he was calling, and that all he wanted was to discuss a technical matter with Dr. Blank. By this time she seemed to be of the opinion

that he was either vicious or crazy. Apparently visitors to see the doctor were not an everyday occurrence. "I don't think you can see him," she finally said, "I'll let you talk to a Mr. So-and-so." You can leave out the "Mr." as you read that sentence and you will have a pretty good understanding of the gentleman to whom she referred him. Mr. So-and-so was a portly, pompous person and an officer in the company. Once more the man told his story of having nothing for sale and of wanting to discuss a technical matter with the company's chief chemist. Then came a remark which probably should be regarded as a classic. Said Mr. So-and-so, "You can't see him. We keep our chemists in their place." So the man had to call on Dr. Blank at his home that evening.

Unpleasant as this story is, it does have a happy ending, for it can be reported that the concern with which Mr. So-and-so was connected has gone into bankruptcy. But the point of view that a chemist is a person to be kept in his place, and that place a minor one, is, unfortunately, one which some industries still hold. Of course, it is probably our own fault in part, for many of us have insisted on

regarding our science as something that we had to keep with ourselves in our laboratories. Instead of looking upon it as a tool to aid us in any field of industry where men find employment, whether that field be production, buying, selling, or what-not, we have thought of it as an end in itself. But there is more to it than that. Industry's lack of regard for the chemist cannot be entirely blamed on the chemist himself. For some reason business, in most instances at least, gives its better prizes not to the chemist who figures out the whys and wherefores of things, but to the man who takes that information and uses it to run the factory or to sell the goods. It may not be fair, but it is a fact nevertheless, and it probably will not be corrected until a larger number of chemists have advanced to positions of responsibility and have been able to recognize that a great many different kinds of jobs can be advantageously filled by men with chemical training.

But we have gotten away from our theme. You remember we were discussing what we wanted the industry for which we worked to give us, and now

that we have covered that, let us see what type of business can give it to us.

The first thing we wanted was a living wage, and, since almost any old business can cough up that much for us, there is no choice among industries from that angle.

Our second point was the saving wage; any successful industry can offer that, too, if it wants to. It must, of course, be successful or it cannot afford anything beyond the lowest wage, and also it takes success to make an industry generous-minded. But the "if it wants to" part is important. If one is considering joining a company, probably the best way to judge how well the organization under consideration is likely to take care of him is to see what it has done for the employees who have preceded him. If they have fared well, it is reasonably certain that he will.

Speaking of generous-mindedness, some organizations go so far as to provide pensions for their old employees, thus assuring them of eventual independence of their earnings, entirely aside from whether they save anything else or not. Some companies provide a sick benefit relief that tides

over the hard periods when illness overtakes the employee and makes it impossible for him to work.

When we come to the question of feeling reasonably sure about continued employment we begin to get into a real difference in organizations. Chemistry can be an aid to a great many different kinds of industry. In some, where chemical reactions are involved in the manufacture of the products, chemical aid is indispensable if that industry is to function efficiently and keep pace in its development with its competitors. In others, particularly those engaged in mechanical manufacture, chemistry is a valuable aid in selecting proper raw materials and keeping them up to proper standards, but it is not the fundamental part of the work. In still other businesses, it is painful to recite, the chief function of the chemist apparently is to give the company's advertising department something to write about.

Continuity of employment in the first class is relatively certain, because the business just cannot go on without chemically trained men. In the second class the likelihood of continued activity

is good, for chemical aid is of importance and will probably not be done away with so long as business remains reasonably good. In the third class the permanence of the job is likely to depend on how fresh the eggs were that some major-domo had for breakfast, a situation that is a gamble, to say the least.

Now as to the "getting somewhere" part of our discussion. This divides itself up along very much the same lines as the continuity of employment did. In an industry that is dependent on chemical reactions, the chemist will naturally be more highly regarded than in other industries. Often he is the man who makes things go, always he is the man who knows why they go, who may get the credit when they are made to go right (and who is sure to get something else when they go wrong). He is in the eyes and minds of the men who decide on promotions and his chances of being well regarded are comparatively good. His field for development is not confined to chemical work, and, if he develops an interest in production or sales or buying or accounting, promotion may lie ahead of him in any of those fields.

In the mechanical industries where chemistry is used, although it may be regarded as a valuable and highly respected tool, it does not hold the center of the stage. The men there who are making the "big decisions" are more likely to be mechanically trained, not chemically. While such industries no doubt offer many excellent opportunities, they would seem to rank second to those in which chemistry holds the key position.

And in the third type of industry, where the chemist is something to talk about, he is likely to be talked about within the organization as well as without—and that not particularly to his credit. While even in such an organization he can do a considerable amount of good if given an opportunity, he is regarded as an intruder in most directions, his presence is resented by the men for whom he could do the most good, and his chances of getting to first base are not much above zero.

Chapter VII

THE CHEMIST IN WARTIME

Some create explosives that are simply fit to kill.
But we're chemists.
Boom! Boom!*
We're still chemists.
While others hide a foundry, make it seem a verdant hill.
We're the chemists.
Boom! Boom!
Always chemists.
And some make poison gases, others, dehydrated fruit,
And some seek raw materials that we can substitute
For those we used to use before we had to stop to shoot.
But we're chemists.
Boom! Boom!
We're all chemists.

In time of war, the chemist, like other technically trained men, is likely really to come into his own. Not only are his services needed in direct military matters, but his usefulness in many varied fields of production becomes greater than ever.

* Regarded as more appropriate for wartime than the "Bum! Bum!" of previous chapters.

To consider first the direct war effort, we find research and development work of the type discussed in previous chapters applied to countless military problems. In fact, about the only kind of chemical activity that is not applied to such problems in one way or another is products service work. This does not have such an immediate bearing on direct war studies, for when we are making explosives or poison gases we don't care so much whether the products *please* the customer so long as they *kill* him. Similarly the customer's likes and dislikes are of less importance in the case of a good many of the other war products. Later we shall find that products service work does have its important place in the wartime economy, but it is not on strictly wartime products.

Among the war problems of the chemist some are well known, while others are of such a secret nature that only a handful of people even know they are being worked on.

Of the more obvious studies, poison gas and protection against poison gas are two that immediately come to mind. It is tragic to think that

groups of intelligent, civilized men have to devote their best thinking to problems as fiendish as these, but when fiends are loose in the world we have to be prepared to meet the situations that they may impose upon us, so we try to develop the most telling gases we can and at the same time we try to work out the most effective defense against possible enemy gases.

Another field of war studies has to do with camouflage. Many types of coatings and coverings are used in this work. The matter of selecting the most effective ones, making them available where they are needed and when they are needed, finding preservatives which will keep them fresh looking so they will really "hide," these and many other problems call for solution.

A third field of study has to do with foods. This subject is particularly critical in the present war because the distances over which supplies must be transported are so tremendous and the conditions under which they are to be used are so diverse. If you will remember for a moment the difference between butter that has just come out of the icebox and butter that has stood on the

kitchen table for some time on a hot summer day, you will have an example of the kind of problem that comes up when some of our men are fighting in the torrid tropics while others are in the icy north. The food we send them must be adapted to meet the conditions under which they are operating, and this presents many problems for the chemist—problems of formulation, packaging, and preservation, to mention but a few.

Synthetic rubber is another field that has given chemists a chance to contribute to the war effort. This particular subject has been such a plum for the politicians, columnists, and publicity seekers that we are apt to forget that behind it all a considerable body of earnest men are learning the facts of synthetic rubber and applying them to the solution of our badly tangled rubber problem.

The many new war machines which have been developed have brought problems in their wake for the chemist. For example, the temperatures encountered by a plane at 20,000 feet are quite different from those prevalent at lower altitudes. Lubricants have to lubricate whether the atmosphere is hot or cold, but you will recall that the

lubricant in your car is apt to be quite different if the car is in a warm garage than it is if you park it out on the street some cold night. Lubricants and shock-absorber liquids have to be found which show relatively slight viscosity changes with change of temperature.

The foregoing represent but a few of the types of problems that the direct military effort presents to the chemist. Numerous others could be cited, but in addition to all of these, the chemical problems of normal industry also mount many fold in wartime. Probably "normal industry" is the wrong expression, for in war no industry is normal. What we are really referring to is that part of industry which is trying to supply normal civilian requirements.

Because the necessities of war require the diversion of immense quantities of materials to the war effort and because importation of many raw materials ceases when war breaks out, there develop acute shortages of raw materials for general manufacturing use.

You will recall that in previous chapters we discussed the chemist's search for new raw

materials to make his product better or to make it cheaper. In war his search becomes a mad hunt for raw materials just to make his product. He awakes one morning to find that his usual raw material, which came from the Malay Peninsula or the Philippine Islands, has ceased to come. Or he may find that a domestic material has become so important to the war effort that the government says to him, "You can't have any more." Even if his firm was forehanded and laid in a supply just in case a shortage might develop, the government may come in and say not only, "You can't have any more," but even, "You can't keep what you already have."

Now while practically everyone is willing, and even eager, to make whatever contribution he can to the war effort, nevertheless the shortage of raw materials makes life a touch-and-go affair for the chemist in industry. "Here today and gone tomorrow" may apply to his raw materials, to his packaging supplies, to anything he buys. The substitute he finds when he first studies a shortage problem may be the commodity that is no longer available a week later, so he looks for substitutes

for substitutes. He studies alternate supplies with a frenzy that makes his prewar search for new raw materials look like sheer dawdling.

It is in evaluating the effects of substitutions that the chemist in products service work finds his place of usefulness in wartime. His is the responsibility of seeing to it that, in spite of the raw-material substitutions that have to be made, the performance of products remains up to the prewar standards or as near to them as substitute materials will permit. With the innumerable changes that the critical conditions of wartime necessitate, the work of making sure that products remain of suitable quality becomes a job of constant vigilance, and the chemist trained in products service work is particularly well qualified to evaluate the effect of changes and to make sure that quality does not suffer.

This may be a good point at which to inject a slightly encouraging note into our discussion. While our war studies and the hectic search for suitable materials do mean a tremendous amount of work, they result in a corresponding increase in our learning about the properties of many sub-

stances. As a result, when peace finally comes and our newly accumulated knowledge can be directed toward satisfying peacetime wants, we are going to have substantial improvements on many of the products we buy and in addition we shall have a whole host of new products that would not have been developed had not necessity spurred us on to our feverish war time pitch.

Before we close our discussion of the chemist in war, it would seem worth while to make one observation that may be helpful to some. Because of the big increase in chemical problems that require solution in wartime, the number of positions available for chemists increases also. Now, while jumping around from job to job has never been a very effective way of improving one's professional standing, nevertheless there are always some men who have, for one reason or another, got themselves into jobs for which they are not really very well suited or which do not bring them the progress they feel is due them. For such persons the increased need for chemical help offers an opportunity to locate a more congenial or more promising connection. This is by no means a

suggestion to anyone to make a change without giving the matter very serious thought or to leap without looking, but it does seem proper to point out that, if one feels he should make a change in his position, a good time to do it is when there are numerous other jobs from which to choose.

When one reflects a little over the increased demands for chemists in wartime, he gets a sort of a feeling of satisfaction over his profession that he may sometimes miss in normal times. If people turn to us when the going is hard and there are lots of difficult things to be done, shouldn't that give us just a little "lift"? Somehow it seems good to know that the training that has so patiently been given chemists can enable them to take the wide variety of problems folks need to have solved and come up so often with helpful answers.

L'ENVOI

(whatever that is)

What is a chemist? Well, here we are right back at the beginning again and we haven't yet set down a definition. We have, however, seen some of the diversified lines of work in which the chemist can make himself useful. We have learned something of the characteristics that help make him valuable and a little something, alas, of some of the qualities that handicap him. What we have really seen is that his possibilities for usefulness cover so many fields that the task of telling in a few words just what he is becomes an impossible one. We can, however, conclude with the observation that a chemist is more or less a human being, though not always behaving like one, who is going to come to be welcomed in more and more fields of business activity and industry as people learn more about him and as he in turn learns more about people.